1·0

2·8

2·5

3·15

2·2

3·5

1·1

4·0

2·0

4·5

1·8

1·25

1·4

1·6

NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

EVALUATION OF BODY COMPOSITION OF

HUMAN SUBJECTS BY MEANS OF

VISUAL APPRAISAL

Annual/Final Report

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EVALUATION OF BODY COMPOSITION OF HUMAN SUBJECTS
BY MEANS OF HEIGHT, WEIGHT AND VISUAL APPRAISAL

DAMD17-74-C-4072
Annual Report

This research project was designed to test the hypothesis

that a score card could be developed for visually estimating the

body fat of people that would be as precise as the expensive,

time-consuming sophisticated instruments conventionally used to

predict body fat. It was assumed that the proposed visual appraisal

methods could be taught easily to untrained judges.

Data on the true body composition of human subjects is never

available, so that unlike animal research in body composition, it

is possible only to compare one method of estimation with another.

The principal techniques traditionally used for this purpose have

been 1) volumetric densitometry or specific gravity determined

by water displacement, 2) ^{40}K determination by whole body counters,

3) total body water determination by dilution of tritium or deuterium

and, 4) skinfold thickness. Such simple measurements as weight and

waist circumference have also been shown to be related to body

composition.

The subjects for this study were all male students at CSU in

the age group 18 to 25 and were selected to represent a typical cross

section of young males.

A score card to evaluate subjects in terms of body fat, muscling and frame size was developed by our research team composed of people with experience in judging. Our judges worked out a consistent scoring program by comparing scores on live subjects and with pictures of subjects. The score card developed and used for this study is shown in the Appendix.

With this score card and pictures we proceeded to train a group of inexperienced judges by pointing out to them how we made decisions for scoring each feature; frame, muscle and fat. After coaching and training with pictures, the novice judges joined the judging team to evaluate live subjects. The scores recorded by novice judges were coded separately so that the two categories of judges could be treated separately in the statistical analyses.

Statistical analyses were planned by Dr. Sutherland with the assistance of the CSU Statistical Laboratory with most of the computations carried out with the University's CDC computer.

Scores for the three body characters; frame, muscle and fat were recorded by judges and analyzed to determine:

1. The relative performance of experienced and inexperienced judges.

2. The agreement among judges in scores on the same individual on the same day.

3. The repeatability of judges in scoring the same subject on different days.

To obtain this information an analysis of variance was performed

to determine variance due to days, subjects within days, and judges within subjects within days. A summary of means and standard deviations is presented in Table 1 for scores recorded on a) live subjects and b) photographs of subjects. Photographs were not available for all of the subjects so the two groups are not identical. Further, the scoring system for frame was changed from a 3 point scale used for live subjects to a seven point scale for photo judging, as a result of our dissatisfaction with the narrow limits imposed by the former.

It can be seen in Table 1 that the mean scores were nearly identical for experienced and novice judges when evaluating live subjects. However, when evaluating photos the mean score assigned by novices was slightly higher for muscle and lower for fat than that assigned by experienced judges.

The standard deviations around the mean exhibited by individual judges on a given subject were quite similar for experienced and novice judges except in the case of fat scores on live subjects and of frame scores for photographs. In the fourth column is presented the standard deviation due to a combination of judge variation and true variation between subjects which indicates that 60-80% of the variation was due to judges.

The coefficient of variation for judges on a given individual ranges from 15-20%, which is well within the limits of expected variation in biological experimentation.

The variation due to day effect was minimal and amounted to only 1 to 5% of the total variation. This indicates reassuringly that judges were rather consistent in their evaluations from one judging

Table 1. Mean Visual Appraisal Scores Variation for
Judges and Subjects in Person and from Photographs

In Person

		Mean Score	SD due to Judges	CV	SD Judges & Subjects	CV Judges & Subjects
Frame	Exp	1.997	.443	22.19	0.50	25.04
	Novice	1.983	.445	22.43	0.39	19.67
Muscle	Exp	3.920	.612	15.60	0.95	24.23
	Novice	4.000	.540	13.50	0.77	19.25
Fat	Exp	3.630	.773	21.29	0.98	27.00
	Novice	3.621	.594	21.28	0.94	25.96

Photo

		Mean Score	SD due to Judges	CV	SD Judges & Subjects	CV Judges & Subjects
Frame	Exp	3.754	.582	15.50	1.02	27.17
	Novice	3.800	.750	19.74	1.01	26.58
Muscle	Exp	3.863	.653	16.90	0.96	24.85
	Novice	4.058	.617	15.21	1.00	24.64
Fat	Exp	3.417	.650	19.04	1.04	30.43
	Novice	3.772	.663	17.57	0.93	24.66

Exp = Experienced judge

Novice = Inexperienced judge

SD = Standard deviation

CV = Coefficient of variation

session to another, and did not change their standards over time.

Table 2

Repeatability of Judges

	Frame		Muscle		Fat	
	Photo	Live	Photo	Live	Photo	Live
Experienced	.68	.22	.55	.59	.85	.62
Novice	.45	.27	.61	.51	.49	.33

Table 2 presents the estimates of repeatability for judges, or
in other words, how well the judges agreed among themselves in scoring
a given individual on a given day, probably the most valid evaluation
of the visual appraisal method. The data indicate that the experienced
judges had, as expected, a somewhat higher repeatability in almost
all cases, which is again reassuring; but it was also encouraging
that the novices performed nearly as well as the experienced judges,
encouraging evidence of the success of our training methods for judges.
Novice judges were more repeatable (i.e. in slightly closer agreement)
on muscle scores, possibly because the average person is more accustomed
to appraising muscle development but not so experienced in distinguishing
the more subtle indications of differences in fat which are generally
hidden by clothing habits.

A comparison of live and photo judging reveals a large difference
in the repeatability of frame scores; this is unquestionably attributable
to the shift from a 3 to a 7 point scale, which allowed a much more

precise evaluation of the individual differences. Repeatability for
fat scores was also higher for photos which may very well be attributed
to added experience, because much of the photo judging was done later
in the project, by which time the "novices" were becoming much more
attuned to the requirements.

Last year a similar study of repeatability was made of scores on
live subjects and the results were frame: 0.36, muscle: 0.27, and fat: 0.65.
These results indicate significant improvement in the consistency of
our judges in one year's time.

In summary we can say that our experienced judges have a fairly
high repeatability of scores and that we have been able furthermore
to train in a relatively short period of time, judges who can do nearly
as well as the experienced ones. It should probably be acknowledged
however that although we selected male judges with no experience in
livestock judging or human appraisal, it is quite possible that students
and faculty at Colorado State University are more aware of judging
techniques than are, for example, medical personnel who will presumably
be those most interested in the present results.

Visual Appraisal vs Conventional Methods

Comparisons of visual appraisal with conventional methods were made by determining the simple linear correlations between the visual appraisal scores for the three characteristics (i.e. fat, muscle and frame) and the fat estimates derived by the conventional methods. The correlation with height, weight and waist circumference was also included.

Fat score by visual appraisal had a fairly high correlation with the fat estimates obtained by other methods but, by contrast, neither muscle nor frame score were very closely related to conventional fat estimates. Body weight, waist circumference and skinfolds are known to be significantly correlated with fatness (Krzywicki et al 1974).

A summary of the more interesting relations is presented below in Table 3.

Table 3.   Correlations of fat estimated by three methods with other measurements

	Fat % by	Whole Body Counter	Volumeter	D$_2$O Dilution
fat score		.56	.42	.69
weight (kg)		.67	.48	.60
waist (cm)		.49	.39	.40
skinfold-scapula		.50	.39	.44
Muscle Score		-.06	.17	.04
Frame Score		-.27	-.17	-.20

This indicates rather similar relations for all of the first four measurements (reading down each column) with fat estimates. In two of the three correlations body weight was even superior to fat score while both were superior to waist or skinfold measurements. Finally, the correlations between muscle or frame score and the fat estimates were very low.

In this comparison, the highest single correlation is between fat score and percent fat estimated by D_2O. This is an encouraging result because animal studies involving slaughter and chemical analysis indicate that body water usually provides the most reliable estimate of body composition, probably because water represents the largest single component of the body. Densitometry tends to provide poor estimates in animals containing a low percentage of fat (Ward and Johnson, 1973) and although one would anticipate that the same conclusions would apply to the human body there is little likelihood of proving it. Some of our subjects had a low percent of fat and this may explain the lower correlation between fat estimates by visual appraisal and volumeter as compared to other methods. One possible evaluation of the relative accuracy of the present estimates in comparison to the standard methods is to compare the correlations between the former and the latter from Table 4 with the inter-se correlations of the standard accepted methods, shown below in Table 4.

Table 4

	D_2O	W.B.C.
Vol.	.67	.69
D_2O		.88

The r values in Table 4 are of the order of those found for a larger sample of males by Krzywicki et al (1974). However they are not perfect

correlations by any means, and provide no definitive answers as to which is the most reliable system for determining body composition. WBC x D_2O are rather closely correlated to each other at .88. This may well reflect their joint accuracy; the fact that both are also about equally and less closely correlated with the volumeter estimate of fat, the r values being .67 and .69, supports the contention that the volumeter estimate is somewhat less reliable than the other two conventional methods.

The inter se correlations of the standard methods are indeed somewhat higher than those between the proposed and standard measurements, shown in Table 3. With the previously mentioned exception of WBC x D_2O, the r values range from only 0.4 to 0.7 which means that in no case is more than 50% of the variance in fat percentage as estimated by standard methods accounted for by the judging techniques although the results were generally as good as comparisons between standard methods.

Multiple Correlations

In the next phase of the analysis measurements were combined to determine whether the residual variance could be reduced, that is, whether a combination of visual appraisal and other measurements would provide a more "accurate" (as defined above) estimate of body fat.

Stepwise multiple regression analyses were performed to determine the relative importance of the nine different independent variables measured for explaining the body fat estimates derived by the standard methods (i.e. D_2O, WBC and volumeter).

Those factors statistically significant in accounting for the variance are presented below in Table 5.

Table 5. Stepwise multiple regression analysis (R^2)

Fat % Determined By:

D_2O			WBC			Volumeter		
Independent Variables		R^2	Independent Variables		R^2	Independent Variables		R^2
1.	Fat score	.48	1.	Weight	.45	1.	Weight	.23
2.	Weight	.61	2.	Fat score	.55	2.	Muscle score	.46
3.	Muscle score	.69	3.	Muscle score	.61	3.	Height	.51
4.	Waist	.72	4.	Height	.66	4.	Triceps	.54
5.	Tricep	.76	5.	Waist	.67	5.	Frame	.56
			6.	Tricep	.68	6.	Waist	.59

It is apparent that the independent measurements compare better with the fat estimates derived from D_2O and as pointed out above, D_2O should provide theoretically the best estimate of body fat. The combination of fat and muscle score with the easily obtained measurements of weight and waist account for 72% of the variance; addition of a skinfold measurement further increased this to 76%.

As compared to WBC estimates, essentially the same sequence of measurements was found although weight entered before the fat score; but again a combination of fat and muscle scores and a simple measurement, height, accounted for most of the variance. The total variance accounted for was however less than in the case of D_2O.

The measurements were considerably less closely related to the fat estimates from the volumeter, and the sequence of entries was even considerably different; for example, fat score was entered as number 8 in the sequence.

Summary

This research was designed to evaluate visual appraisal as a method of estimating body composition of male subjects in the age range of 18 to 25 years. The project was designed to compare the results obtained by visual appraisal with estimates of body composition obtained by the conventional methods of skinfolds, ^{40}K by whole body counting, by deuterium oxide dilution and by densitometry. If the method proved feasible, it was important to evaluate the competence of various judges and the success of training inexperienced judges.

A score card was developed for visual appraisal of the subjects for whom body composition estimates were also available from the conventional methods. A statistical analysis of the data indicated that 40 to 70 per cent of the variation in fat percentage could be accounted for by the visual appraisal method. The visual appraisal proved to be about as effective as any of the conventional methods in estimating fat; this conclusion is reached from the fact that the visual appraisal method agreed with the conventional methods about as closely as the latter agreed among each other.

When simple additional measurements such as weight and waist circumference were added, 70-75 per cent of the variation was accounted for by visual appraisal in conjunction with these; skinfold measurements improved the accuracy only slightly.

Experienced judges had repeatability values of .50 for frame scores and .85 for fat scores. Novice judges had somewhat lower but quit acceptable repeatability.

Visual appraisal plus weight and waist measurements were shown to be as reproducible, and presumably as accurate an indicator of body composition of young males as the more sophisticated and expensive methods commonly used for this purpose. Inexperienced judges were easily and rapidly trained to do nearly as well as personnel experienced in visual appraisal.

Acknowledgements

We wish to acknowledge the assistance of the following people
without whose help this project could not have been completed.

Sharon Svalberg

Dr. James Johnson

Harry Krzywicki

Max Morton

Dan Carnevale

the members of the Farmhouse and Alpha Gamma Rho fraternities

and graduate students of the department of Animal Sciences.

Training Guide for Male Visual Appraisal Judges

The following is a guide for inexperienced visual appraisal judges. Photographs are included depicting the various judging scores as described in the score card. Frame is on a three point scale, muscle development and fatness are on seven point scales.

SCORE CARD FOR VISUAL APPRAISAL

OF

YOUNG MALE SUBJECTS

EXERCISE OR WORK HABITS

This information to be obtained from subject: (1) Heavy physical
labor 8 hours per day, or several hours exercise, (2) Light but
non-sedentary work, (3) Sedentary work but regular exercise
i.e. several times per week, (4) Sedentary light exercise i.e.
occasional workouts, walking, biking, etc., and (5) Very little
exercise.

FRAME

Refers primarily to bone structure and is independent of height and
weight which are recorded separately. Categories: (1) rugged,
(2) medium, and (3) slight.

MUSCLE DEVELOPMENT

Attempts to rank muscular development as apparent from casual ob-
servation in subjects standing in a normal relaxed position dressed
in shorts.

Categories: (1) Extraordinary, (2) Very heavy, (3) Heavy, (4) Medium,
(5) Below average, (6) Slight, (7) Under-developed.

FATNESS

Attempts to rank total body fat content (without relation to distribution)
as indicated by fat pads, rolls, or general appearance of soft structures.

Categories: (7) Obese, (6) Very fat, (5) Fat, (4) Moderate (average for
teenage male), (3) Slightly thin, (2) Thin, and (1) No obvious fat.
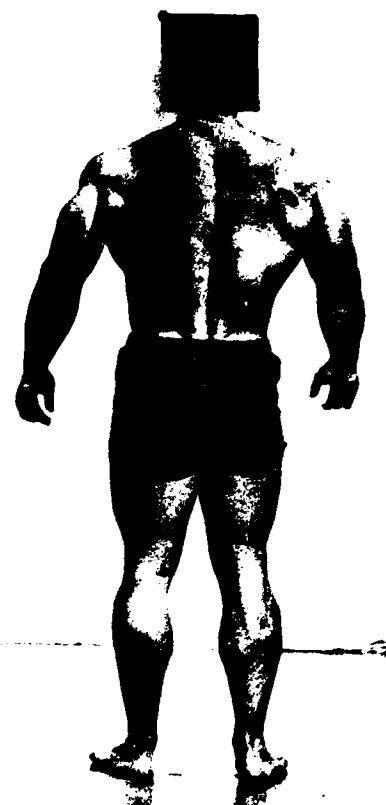
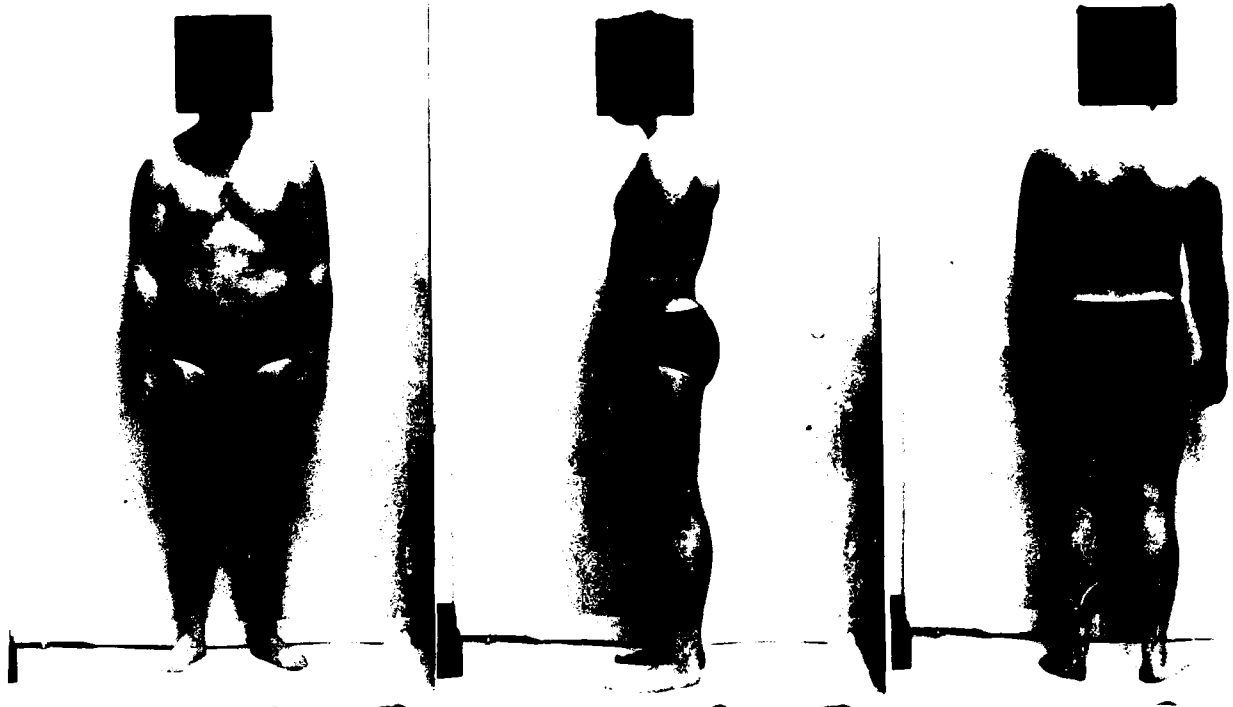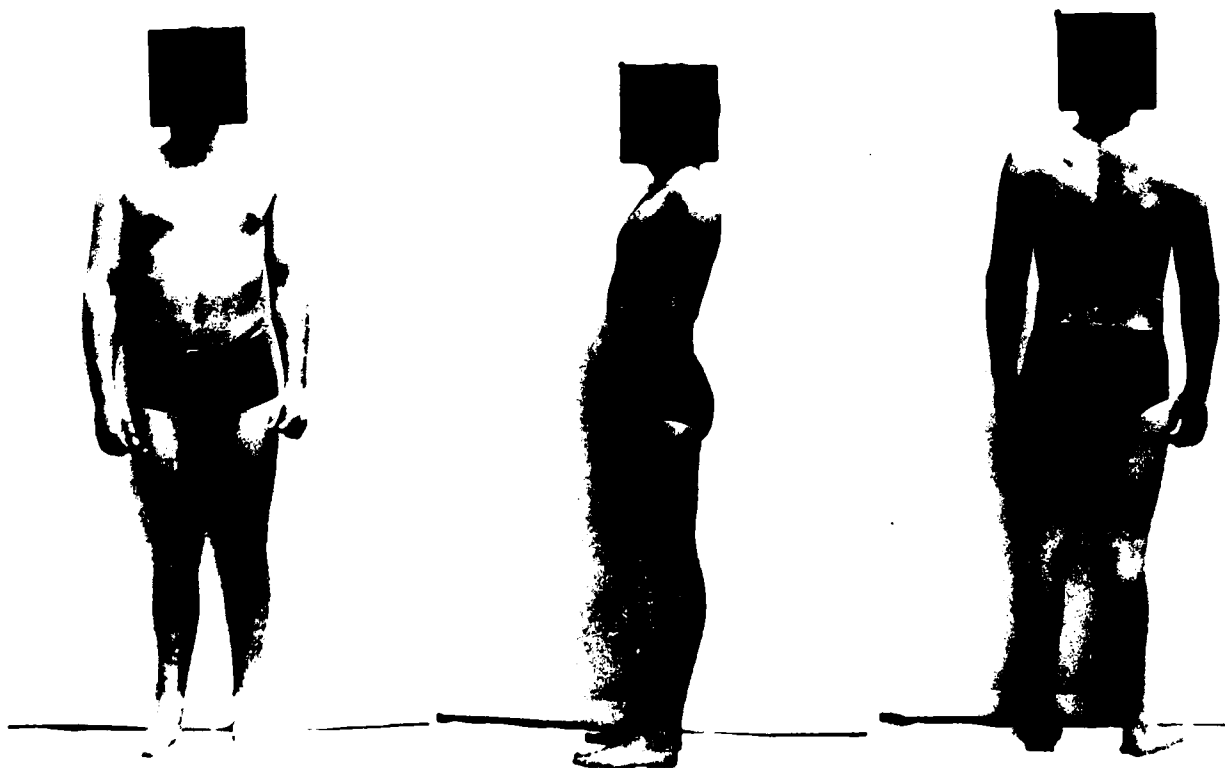Frame Score 1

Frame Score 2
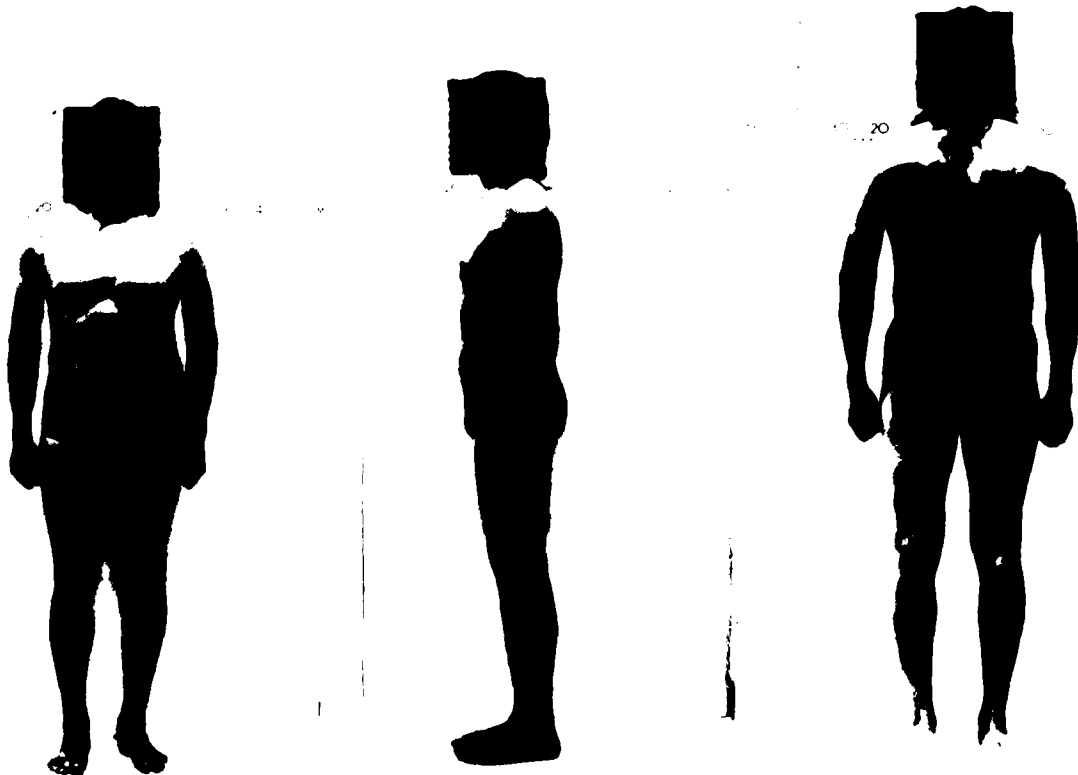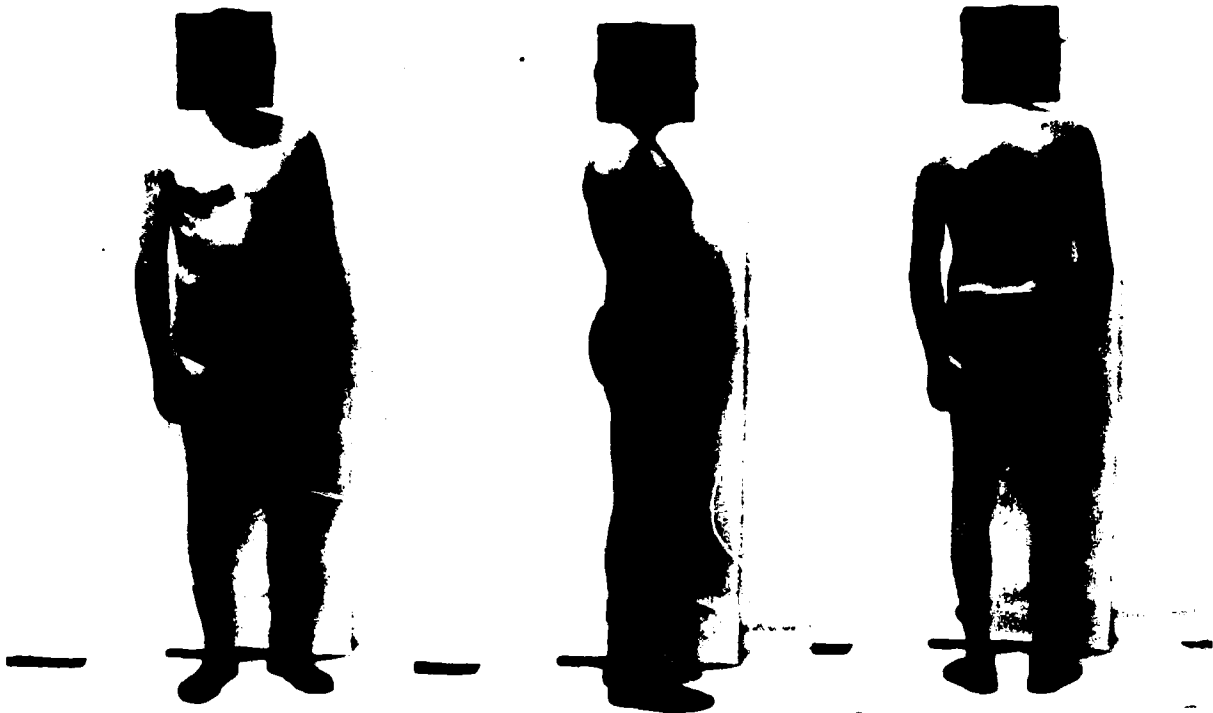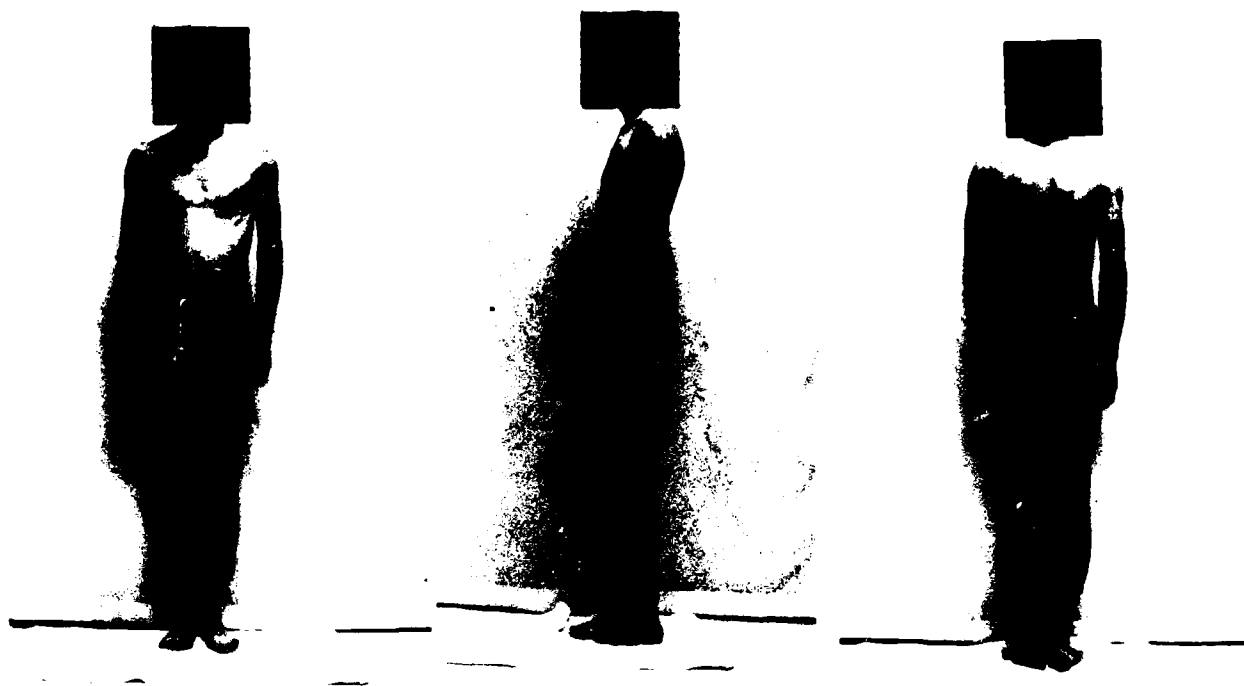
Muscle Score 1

Muscle Score 2

Muscle Score 3
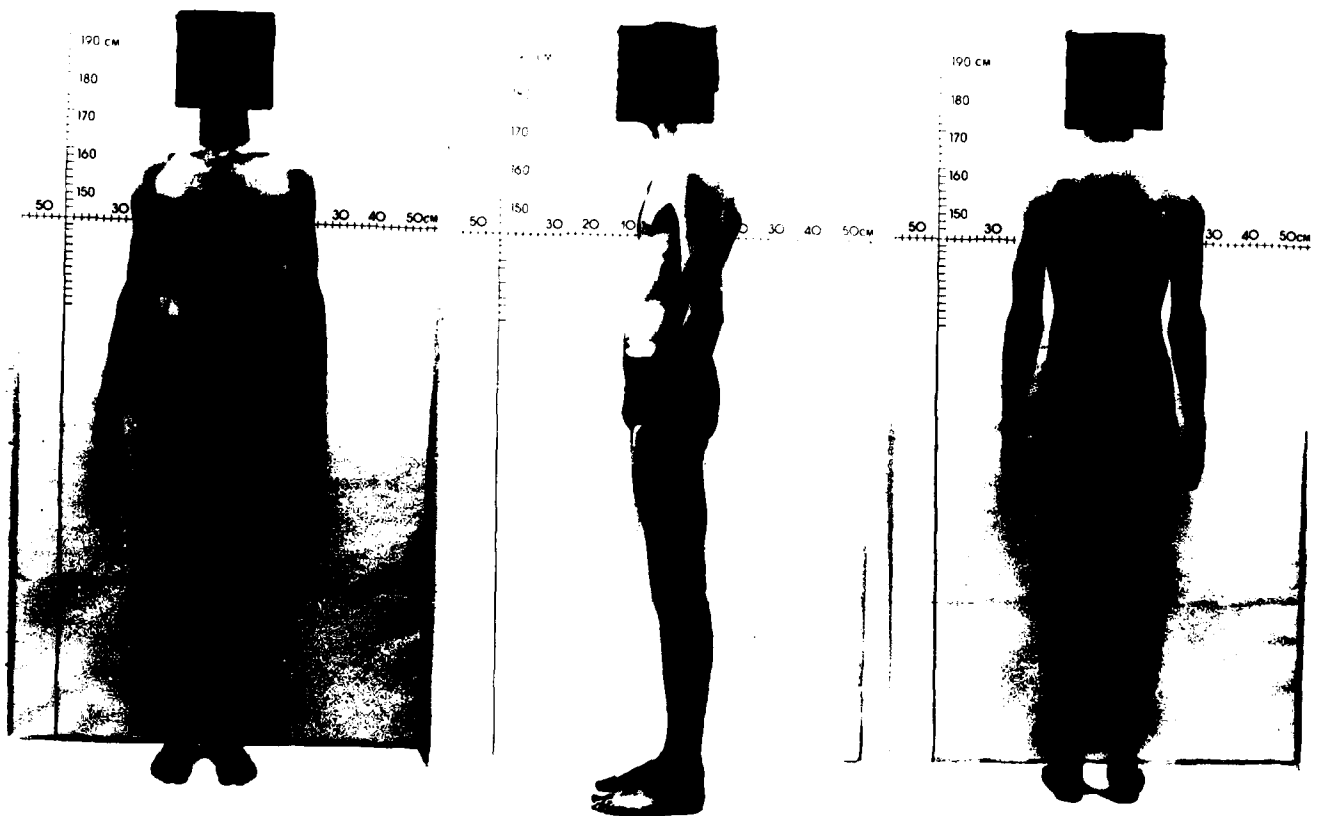

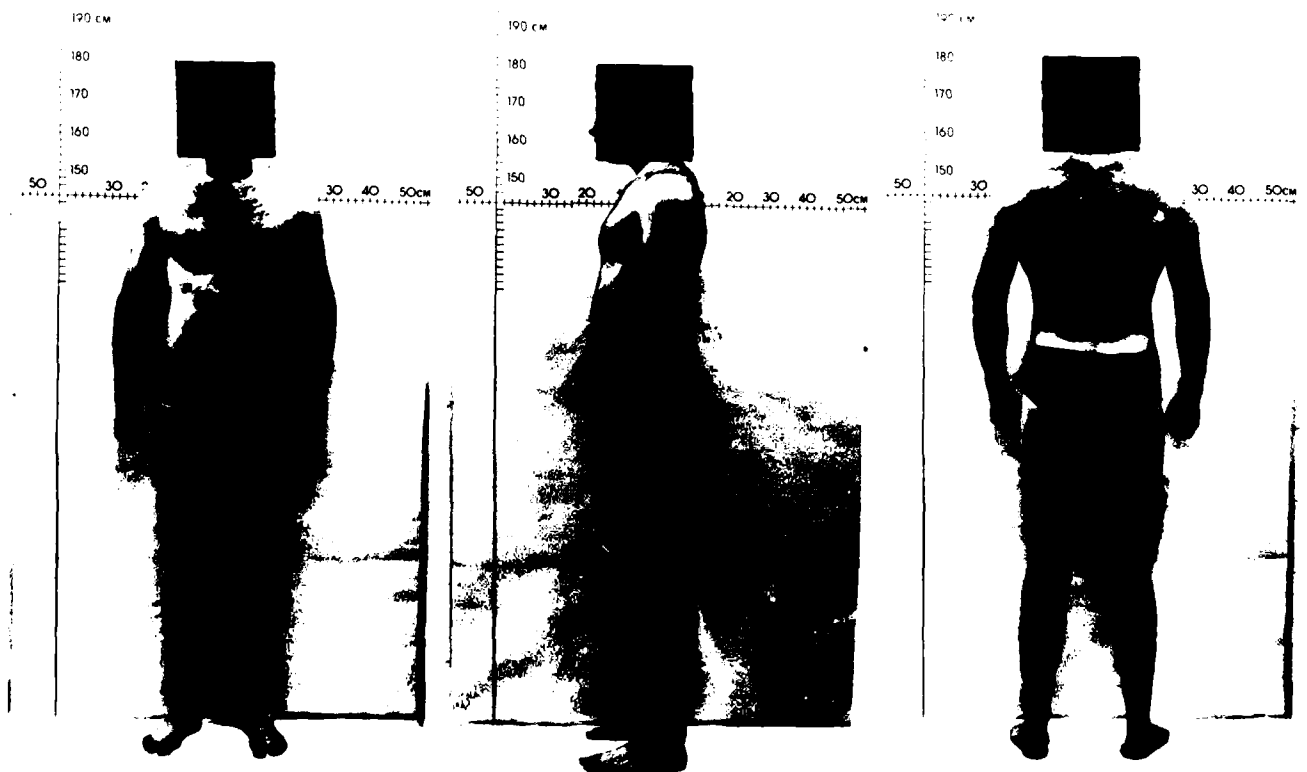Muscle Score 4

Muscle Score 5

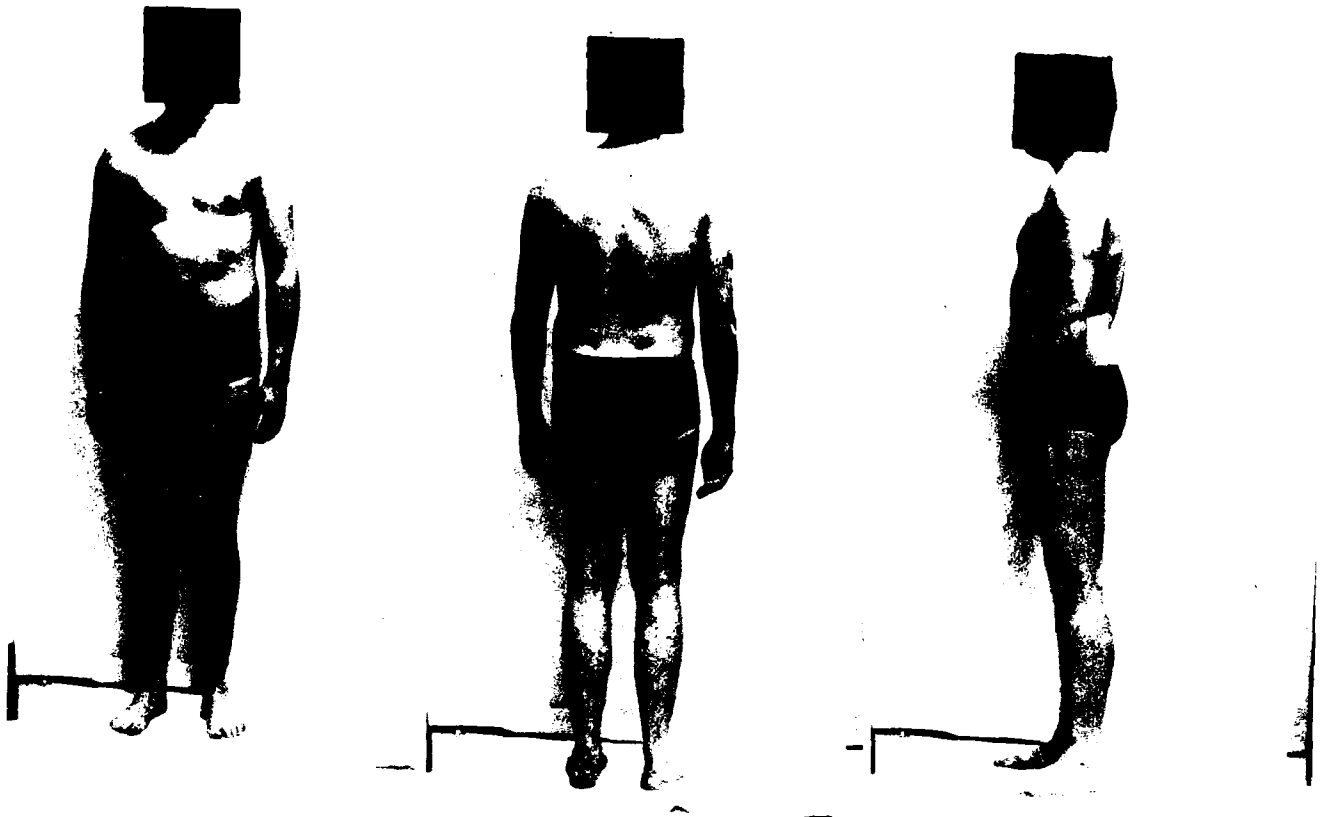Muscle Score 6

Fat Score 1
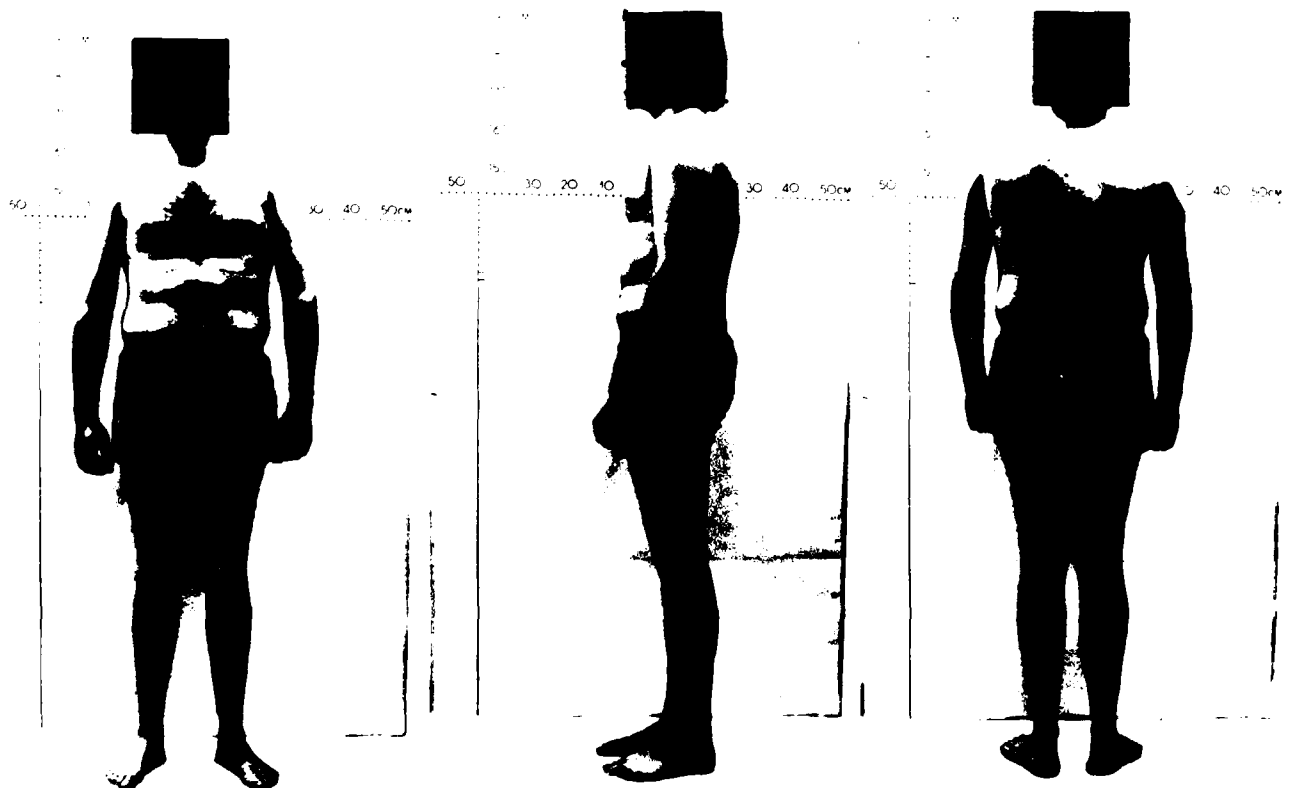
Fat Score 2

Fat Score 3

Fat Score 4

Fat Score 5

Fat Score 6

APPENDIX

For comparison with our visual appraisal system body composition
was determined by deuterium oxide dilution, ^{40}K whole body counting,
volumeter measurements and anthropometric measurements. These methods
are described in the methods portion of the appendix.

Methods

1. Deuterium Oxide Dilution - Determination of Total Body Water

Urine samples from 34 subjects were collected 2, 4, and 6 hours
after oral consumption of 110 grams of 99.8% D_2O[1]. Samples were
centrifuged to remove solid material and frozen at -5C until analyzed.
Upon analysis samples were thawed and equilibrated to room temperature
(29C-30C). Aliquots of 75 to 100 μl of urine sample were injected
into the calcium hydride (CaH_2) cartridge (see Appendix fig 1) which
generated a deuteriated hydrogen gas (H_2-HD). The H_2-HD gas was then
injected into a thermal conductivity gas chromatograph[2] via a special
seven port valve (see Appendix fig 2). The resulting chromatograms
were printed on a 0-1 m.v. strip chart recorder[3]. The peak heights
resulting from deuterium in the urine samples were compared with
those from a set of 7 standards. Standards were run along with samples
daily ranging from 0 percent to .6 percent deuterium oxide by weight
(at .1% intervals).

---

[1] 99.8% D_2O purchased from Koch Isotopes, Cambridge, Mass.

[2] Varian Arograph Model A-700

[3] Varian Aerograph Model 20

Initially, when we calculated weight of fat by equations 1, 2, and 3 we obtained some negative fat values which indicated some error in the method or the calculation.

Equation 1 $$\frac{\text{grams } D_2O \text{ consumed}}{\text{g } D_2O/\text{liter urine}} = \text{Total Body Water (kg)}$$

Equation 2 $$\frac{\text{Total Body Water (kg)}}{\% \ H_2O \text{ in FFM (73\%)}} = \text{FFM (Fat Free Mass)}$$

Equation 3 $$\text{Fat (kg)} = \text{Total Body Weight (kg)} - \text{FFM (kg)}$$

Our values for percent deuterium concentration-urine were comparable to those that Nielsen et al (1971) obtained for human subjects; therefore the figure we were using for percent water in the FFM seemed the most likely source for error. Krzywicki et al (1974) had used 73% water in the FFM in humans, but this figure like most figures for human body composition lacked large bases of supportive data and in many instances are based on data from other species. To derive a more definite figure for the percentage of water in the FFM of our subjects, we conducted the following procedure:

1. The fat in kilograms derived from ^{40}K whole body counting, volumeter and anthropometric measurements were averaged for each subject (25 subjects total).

2. Total body weight - weight of fat equals the weight of fat free body mass.

3. Percent water in the fat free mass was then calculated by:

Equation 4 $$\text{Total Body Water} = \frac{\text{Grams } D_2O \text{ Intake} = 110 \text{ g}}{\% \ D_2O \text{ in urine x 10 (from } D_2O \text{ analysis)}}$$

Equation 5   % H_2O in FFM $= \dfrac{\text{Total Body } H_2O \text{ (from Equation 4)}}{\text{Kgs FFM (from Step 2)}}$

The average percentage of water in the fat free mass of 25 subjects was then determined to be 78.11. By using this factor positive values for fat percentage were obtained for all our subjects. This provides reasonable evidence that the figure of 73% water in the fat-free body is too low.

^{40}K Whole Body Counter

The Whole Body Counter (WBC) functions on the principle of measuring the ^{40}K naturally present in the body (the detector must be shielded from background radiation). The WBC is a compartment shielded by steel and lead (WBC described by Ward and Johnson (1968)) in which the subject is positioned in a reclining chair in close proximity to a NaI crystal detector to count ^{40}K emissions (see Appendix figure 3). In this study male human subjects were in the WBC for 40 minutes (all counts were later adjusted ... 100 minute intervals). Kilograms of fat were calculated according to Equations 6, 7, and 8.

Equation 6 $\dfrac{\text{g K in body}}{.039} = \text{meq}$

Equation 7 $\dfrac{\text{meq K in body}}{\text{g K/kg FFM (from Figure 4)}} = \text{FFB (kg)}$

Equation 8   Body weight (kg) − FFB (kg) = Body Fat (kg)

Volumeter Measurements

A volumeter located in the physical education facility on campus was used as a third means of measuring the fat and fat free masses

in the male subjects. The volumeter tank as described in Appendix figure 5 was constructed out of 1/2" transparent plexiglass with 1¼ angle aluminum corner supports. The tank was calibrated by draining out 50 aliquots (approximately 2 kilograms each) of water, weighing each aliquot to the nearest one hundredth of a gram and recording the centimeters of water level change (centimeters read to the nearest 1/100). Water temperature during calibration and during subject measurement was 30C. The calibration figure was determined to be 2.178 liters of change in volume of water per 1 cm change in water level.

Subject volumeter measurements were taken in the following manner. A null reading was taken. The subject then entered the tank (water was maintained at neck level when subjects were in the standing position) and was allowed time to become accustomed to the volumeter. Readings in centimeters of water were taken while the subject was submerged underwater with the air exhausted from his lungs to the extent possible. Readings were repeated up to six times until a consistent "lowest" reading was obtained. The "lowest" reading was achieved when the subject evacuated the largest volume of air from his lungs. Kilograms of fat were calculated from the following formula (Equation 9):

Equation 9
$$\left[\left[(\text{Lowest Reading} - \text{Null}) \times 2.178\right] - 1.250\right] \times 4.834 = A$$

$$(4.366 \times \text{Body Weight}) = B$$

$$A - B = \text{kgs Fat}$$

Calibration = 2.178 change in l/change in cm

Correction for Residual Lung Volume = 1.250 l

4.834 and 4.366 are conversion factors derived by Allen et al (1960) for conversion of volume to weight.

Anthropometric Measurements

Anthropometric measurements were taken on our subjects as
the final means of quantifying the body compartments. Lange skin
calipers (Appendix figure 6b) were used to measure skinfolds on the scapula
and triceps regions (see Appendix figure 6a). Waist circumference was
measured in centimeters.

All of the above parameters were then calculated as percent fat
by means of regression equations derived from the same data base of
military personnel described by Krzywicki et al (1974). Regressions
were derived by correlating the independent variables (Anthropometric
measurements) to the same dependent variables as used by us in our
statistical analyses (^{40}K whole body counter, volumeter measurements
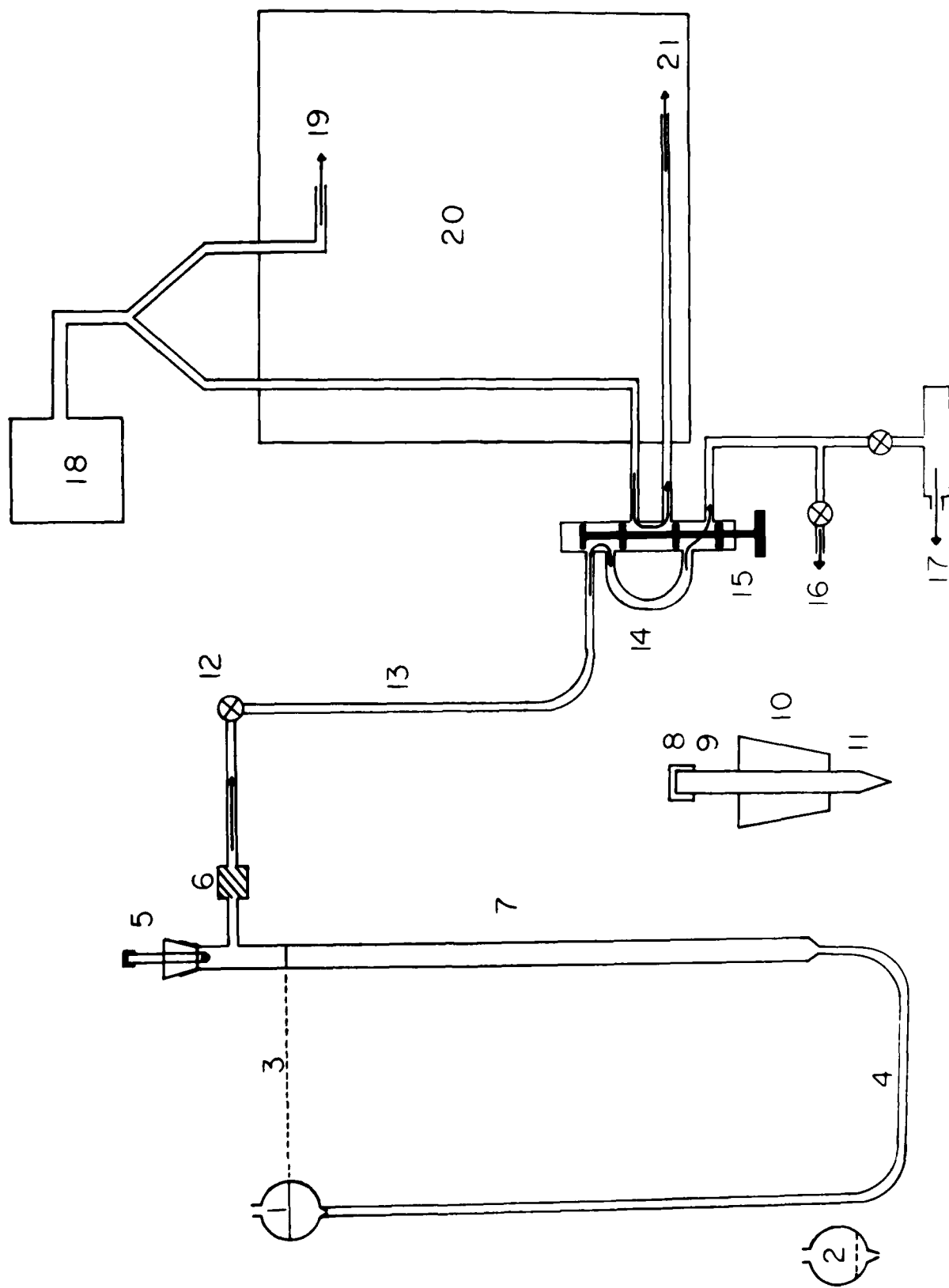and D_2O dilution). Those regression equations are listed in Appendix
Table 1.

Figure 1. Deuterium Analysis Apparatus

Figure 1 Deuterium Analysis Apparatus

Key

1. Hg leveling bulb

2. Level of bulb during evacuation stage and H_2-HD generating step

3. Level of bulb after loading of 5 ml and sample loop

4. Flexible tygon tubing (3 mm I.D.)

5. Calcium hydride generating cartridge (see 8-11)

6. Glass to stainless steel fitting

7. H_2-HD gas collection tube (1.5 cm x 8 cm)

8. Rubber 5 mm x 8 mm serum stopper

9. 8 mm O.D. glass tubing packed with CaH_2

10. Rubber stopper for inserting and sealing cartridge in end of gas-collecting tube

11. Glass wool inserted into tip of cartridge to retain CaH_2

12. Gas valve for controlling flow of H_2-HD gas into sample loop

13. 1 mm I.D. stainless steel tubing

14. 5 ml stainless steel sample loop

15. Special seven port valve positioned in the loading position (see fig)

16. Vent for equilibration of gas pressure when loading sample logs

17. Pump for evacuation of residual gases from glass collection tube

18. Hydrogen pressure tank

19. Reference gas line - 55 ml/min flow rate through detector

20. Gas chromatograph - Varian model A-700 thermal conductivity

21. Carrier gas and sample gas line 55 ml/min flow rate
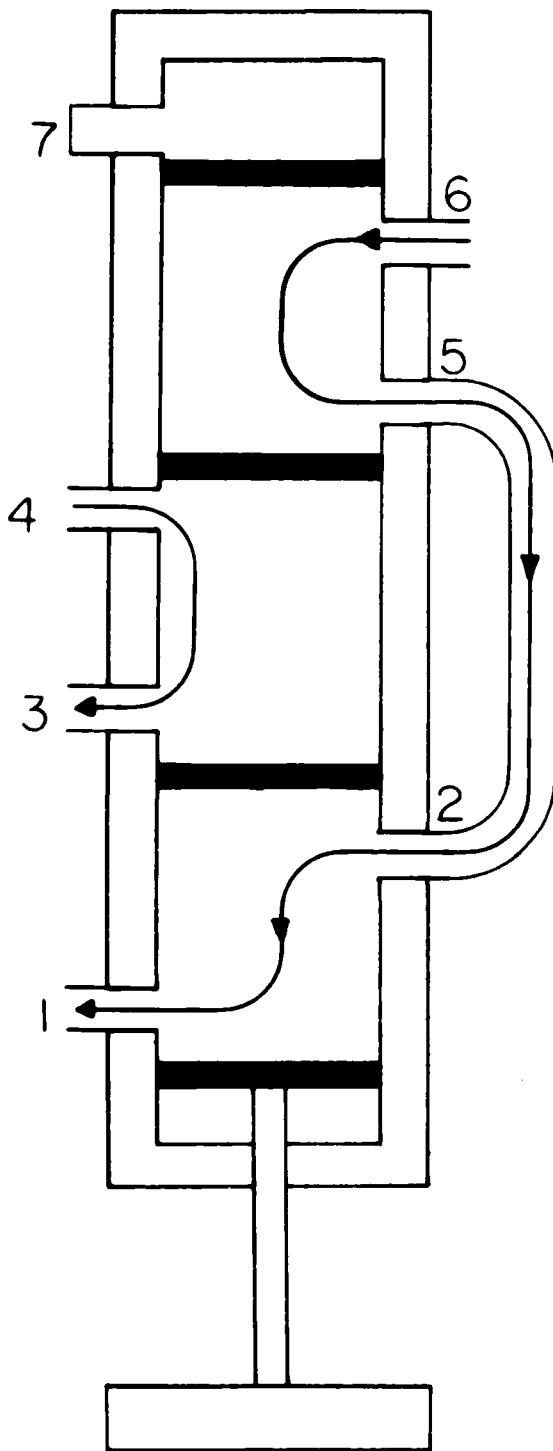
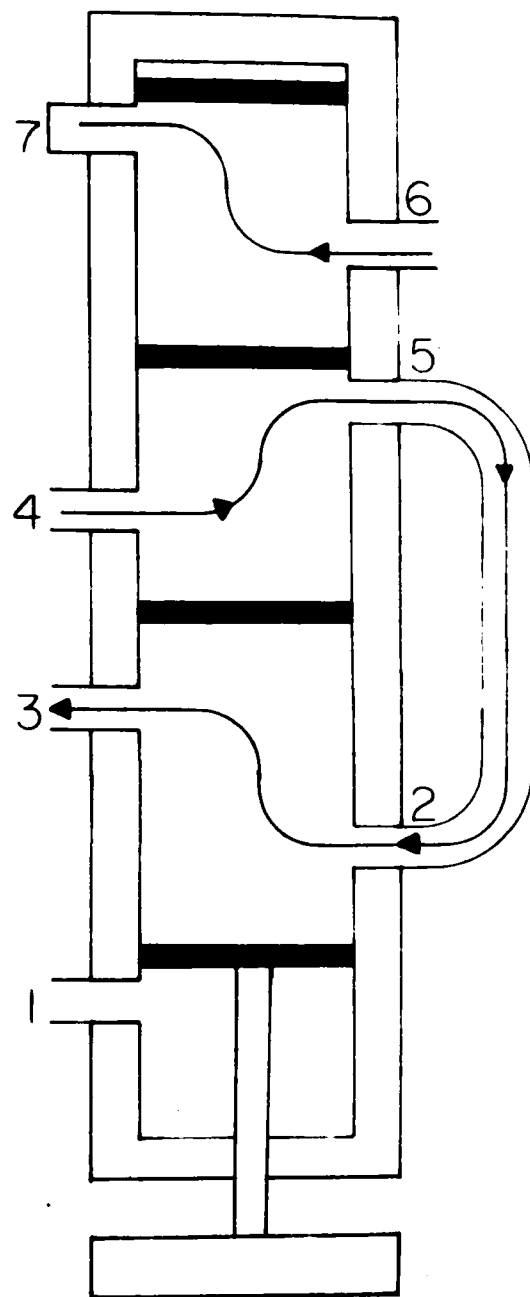Figure 2A   Seven port valve
in loading position

Figure 2B   Seven port valve
in injection position

Figure 2A   Seven port valve in loading position

Key

1. Port leads to pump for evacuation of collection tube and to vent for equilibration of gas pressure in sample loop

2. and 5. Five ml sample loop connection

3. To Chromatograph

4. Carrier gas flow from H_2 pressure tank

6. Flow from collection tube

7. Spare port (no net flow)

Figure 2B   Seven port valve in injection position

Key

1. No net flow

2. and 5. Five ml sample loop connection

3. Sample carried into chromatograph

4. Carrier gas flow from H_2 pressure tank through 5 ml sample loop
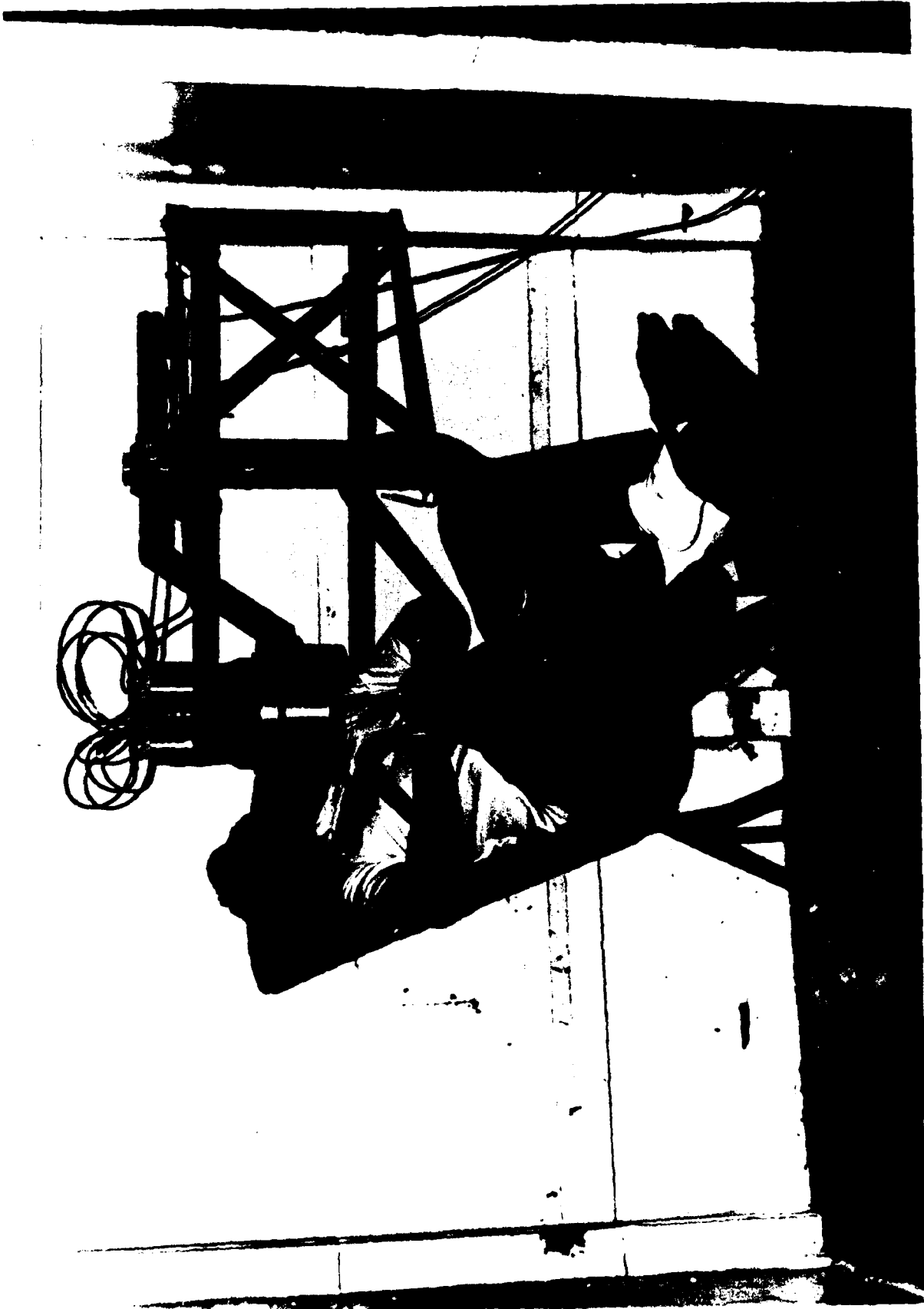
6. and 7. No net flow
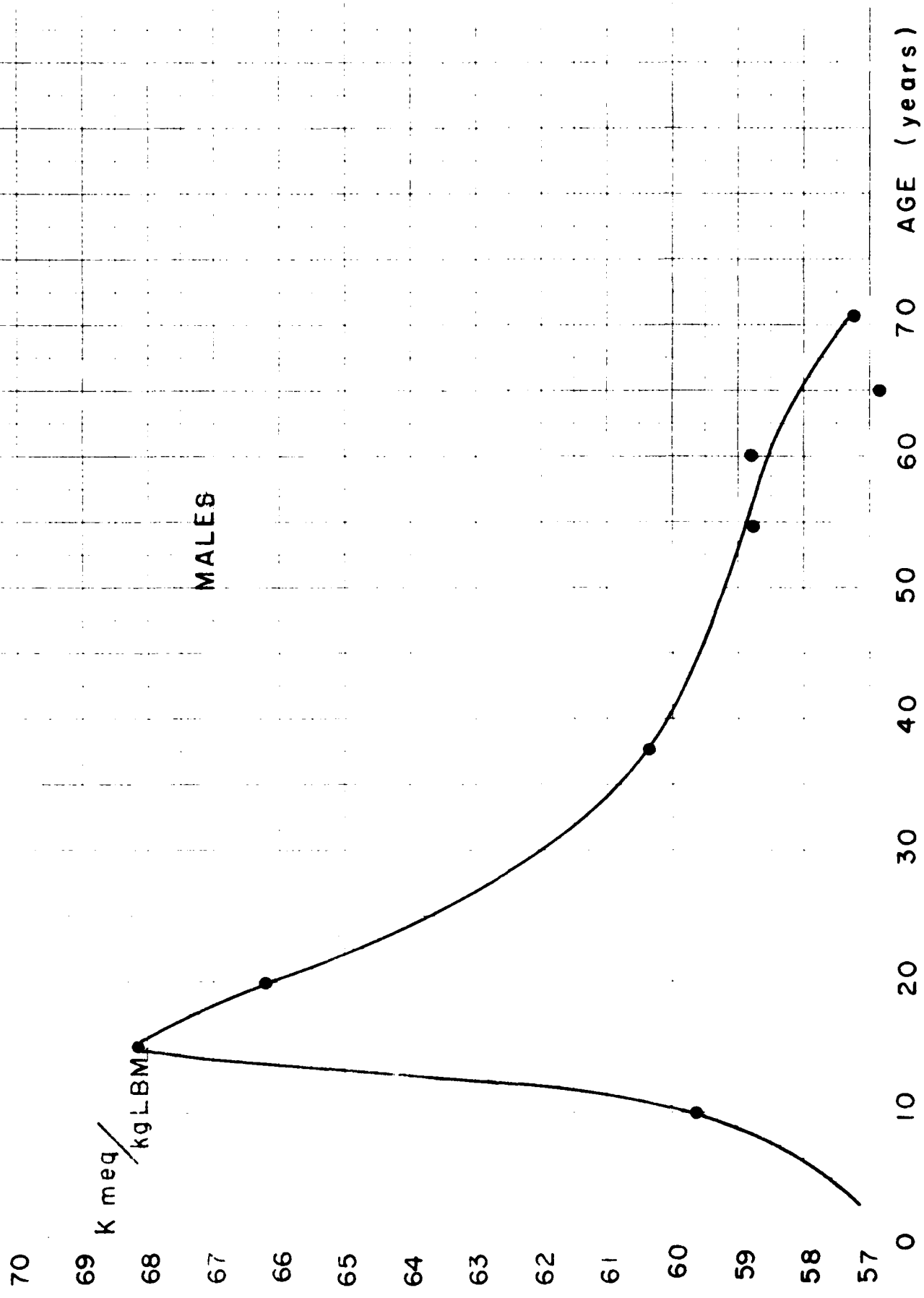
Figure 3. Whole Body Counter

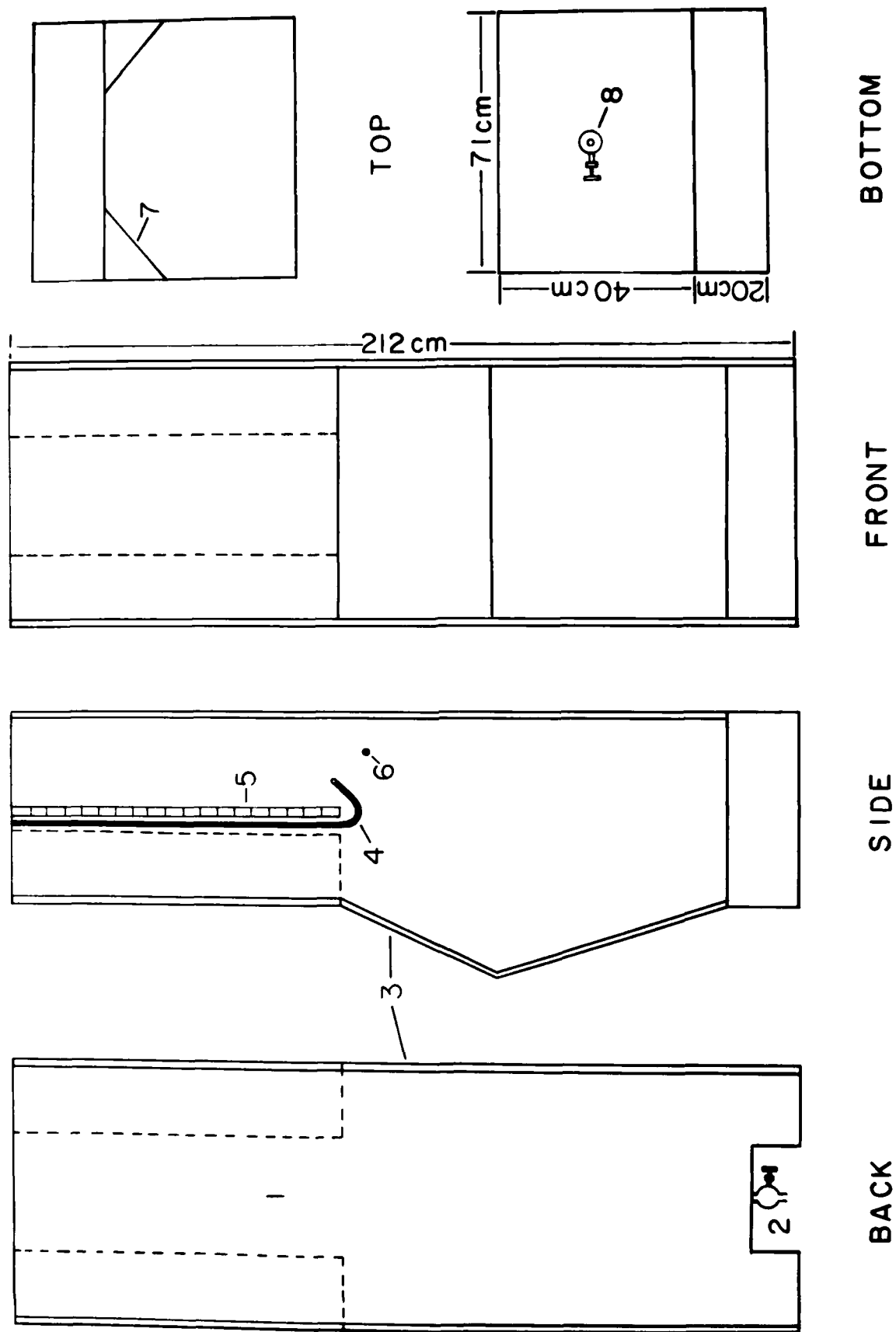Figure 4. Calibration curve for Whole Body Counter

Figure 5. Volumeter

Figure 5. Volumeter

Key

1. Volumeter walls made of 1/2" transparent plexiglass

2. and 8. Drain

3. 1-1/4" angle aluminum corner support

4. Water level tube (3 mm I.D. glass)

5. Stainless steel metric rule (1 mm markings)

6. Drain port used for calibration of tank

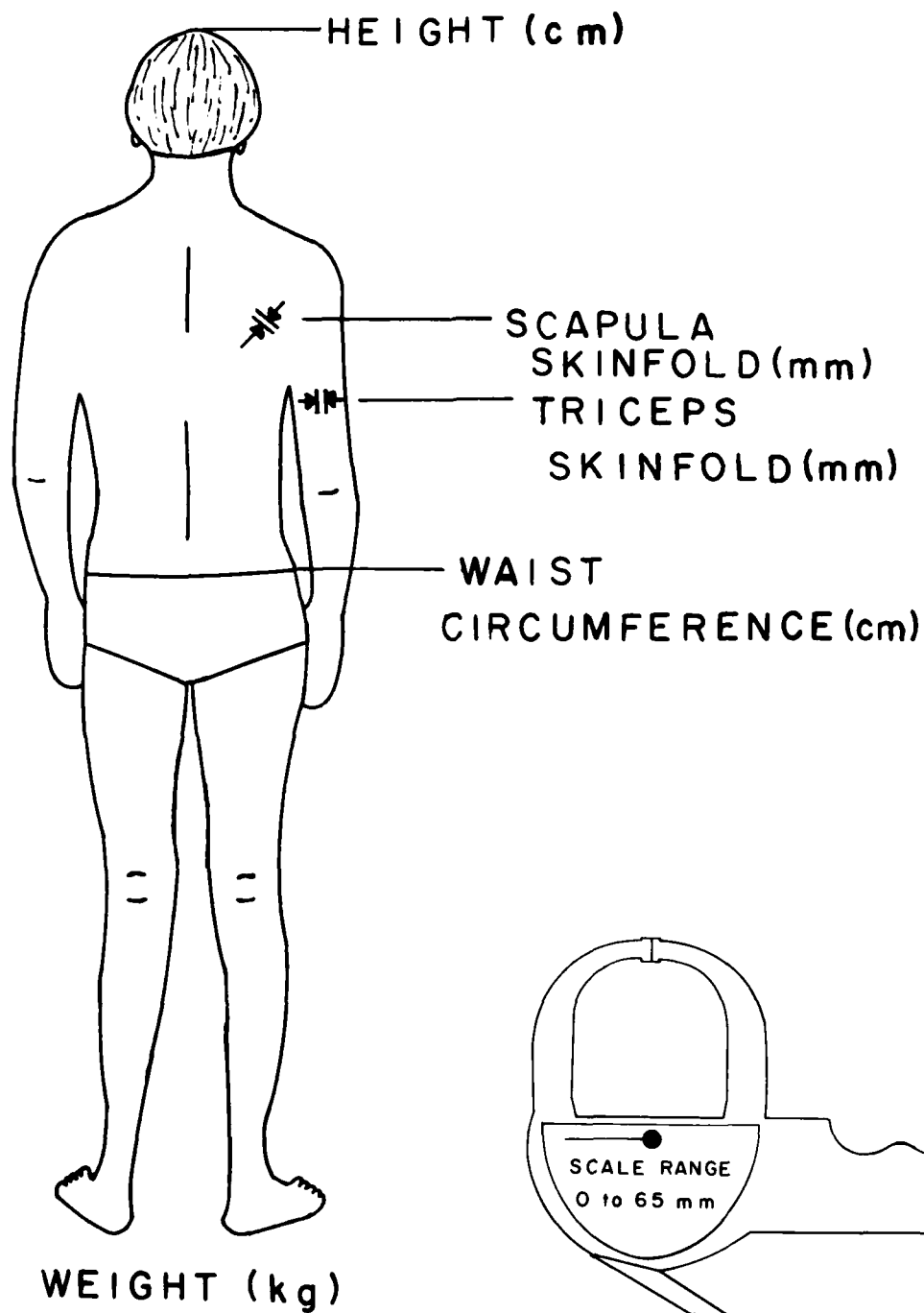7. Interior tank supports--also reduce volume of tank

HEIGHT (cm)

SCAPULA SKINFOLD (mm)

TRICEPS SKINFOLD (mm)

WAIST CIRCUMFERENCE (cm)

WEIGHT (kg)

SCALE RANGE
0 to 65 mm

Figure 6A
Anthropometric Measurements

Figure 6B
Skin Calipers

Appendix Table 1

Values for regression equation y = a + bx

$$y = \% \text{ fat}$$
$$a = \text{intercept}$$
$$b = \text{slope}$$
$$x = \text{anthropometric measurement}$$

Data Source	Anthropometric Measurement	a	b
Volumeter	Tricep (mm)	6.01	.99
	Scapula (mm)	6.05	.75
	Waist circum. (cm)	-77.58	.97
D₂O dilution	Tricep (mm)	12.29	.87
	Scapula (mm)	11.17	.72
	Waist circum. (cm)	-31.94	.63
40ₖ dilution	Tricep (mm)	6.91	1.24
	Scapula (mm)	6.47	.96
	Waist circum. (cm)	-53.94	.87

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